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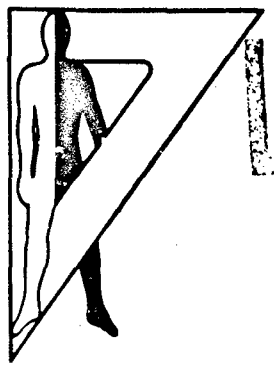

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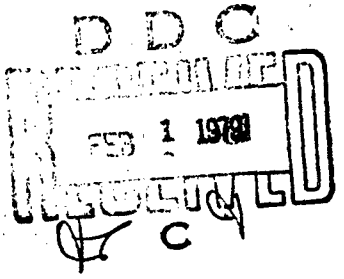
Technical Memorandum 30-78

INTERIM STANDARDS FOR THE CONSTRUCTION OF MOBA STRUCTURES FOR WEAPONS EFFECTS TESTS

Brenda K. Thein
David R. Coltharp



December 1978
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U. S. ARMY HUMAN ENGINEERING LABORATORY
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1. REPORT NUMBER: Technical Memorandum 30-78	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: INTERIM STANDARDS FOR THE CONSTRUCTION OF MOBA STRUCTURES FOR WEAPONS EFFECTS TESTS.	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Brenda K. Thein, David R. Coltharp	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD 21005	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS Code 672716.H700011
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: December 1978
	13. NUMBER OF PAGES: 21
14. MONITORING AGENCY NAME & ADDRESS *(If different from Controlling Office)*	15. SECURITY CLASS. *(of this report)*: Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

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17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, If different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

MOBA
MOUT
Targets
Weapons Effects Testing
Assault Weapons Testing
Combat-in-Cities
Urban Warfare

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report provides a set of interim standards for the construction of MOBA targets for weapons effects testing.

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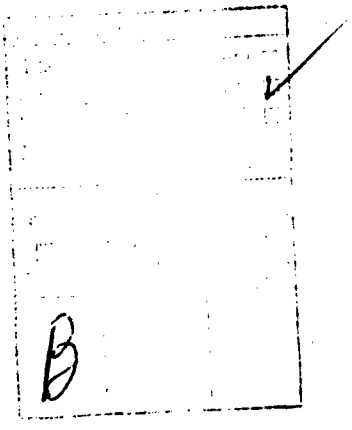
INTERIM STANDARDS FOR THE CONSTRUCTION OF MOBA STRUCTURES FOR WEAPONS EFFECTS TESTS

Brenda K. Thein
David R. Coltharp[1]



December 1978

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U. S. ARMY HUMAN ENGINEERING LABORATORY
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ACKNOWLEDGMENT

The authors wish to express their appreciation to the following individuals who assisted in producing these guidelines.

Mr. George A. Coulter
US Army Ballistic Research Laboratory

Mr. Stephen J. Zardas
US Army Ballistic Research Laboratory

Mr. John H. Keefer
US Army Ballistic Research Laboratory

Mr. Glenn P. Beichler
US Army Materiel Systems Analysis Activity

CPT Robert Clydesdale
US Marine Corps Development and Education Command

Mr. Donald O. Egner
US Army Human Engineering Laboratory

Mr. Ellsworth B. Shank
US Army Human Engineering Laboratory

CONTENTS

INTERIM STANDARDS FOR THE CONSTRUCTION OF MOBA STRUCTURES FOR WEAPONS EFFECTS TESTS

INTRODUCTION

One of the elements of evaluation for Military Operations in Built-Up Areas (MOBA) involves the research and development (R&D) testing of munitions/weapons against various MOBA-type targets, such as masonry walls (buildings) and bunkers.

A problem in this form of testing is the lack of target standardization. By target standardization is meant construction standards such as strength of concrete, reinforcing, mortar mix for walls, and stand-off (i.e., thickness of covering outside of bunker), and timber size and type for bunkers, as well as dimensions such as height, width, thickness. In order to provide a valid evaluation of a munition against MOBA-type targets or comparison between munitions for their MOBA application, it is important to have a baseline or standard against which to test.

Recognizing the need for test targets and the problems of standardization, representatives of the US Army Waterways Experiment Station, US Army Ballistic Research Laboratory (BRL), US Army Materiel Systems Analysis Activity (AMSAA), US Marine Corps and US Army Human Engineering Laboratory (HEL), who have been deeply involved in this type of testing, held a meeting at HEL on 13 April 1978. The information in this report is the "best-effort" product of that meeting and has been concurred with by meeting participants. The purpose of the report, therefore, is to provide standards and design criteria for the construction of walls and bunkers for future MOBA munitions tests.

With regard to wall targets, in the past the munitions tests have been conducted against motel-type structures at the US Department of Energy's Nevada Test Site (NTS), Mercury, Nevada. The walls at NTS were 8-, 10-, and 16-inch reinforced concrete with a compressive strength of 6500 psi, 12-inch brick, and 4-inch brick over 8-inch block. However, as a result of continuous testing, there are essentially no test structures remaining at NTS for future munitions testing. With regard to bunkers, the design, which has been tested at the US Army Armor School, Ft. Knox, KY, and the US Army Infantry School, Ft. Benning, GA, was developed from data provided by the Foreign Science and Technology Center (FSTC) at the request of AMSAA and BRL. The design is representative of a fighting-type fortification that might be encountered in a European conflict. The data provided by FSTC was for a bunker commonly used by the Soviet Army.[1]

It should be noted here that the concrete walls specified in this report are for 3500 psi compressive strength, rather than the 6500 psi compressive strength found in the Nevada walls. A question which immediately comes to mind is how to relate the data from the two different strength walls. An examination of various reports[2,3], reveals that there is an approximate rule of

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[1] Belakon, A. P. Engineer organization of a rifle company defense area. Ministry of Defense, Moscow, FSTC Technical Translation, FSTC-HT-23-1024-70.

[2] Summary Technical Report of the National Defense Research Committee. (Vol. 1) Effects of impact and explosion. Washington, DC: National Defense Research Committee, 1946.

[3] Crawford, R.E., Romesburg, L.E., & Wilson, L.E. Protection from non-nuclear weapons. AFWL-TR-70-127. Mechanics Research Inc., Albuquerque, NM, February 1971.

thumb for estimating the difference in effects for the two compressive strengths. The rule of thumb is that the difference in effects (adjustment factor: a_f) is approximately equal to the square root of the ratio of the two compressive strengths, i.e.

$$a_f \simeq \sqrt{\frac{x_1}{x_2}}$$ where x_1 = Nevada wall compressive strength and x_2 = new wall compressive strength

This rule of thumb should be helpful in adjusting penetration and hole/crater measurements and give an indication of probability of incapacitation (P_I) differences. However, it should be verified with some limited testing utilizing one or more of the weapons/munitions that were tested against the Nevada walls.

Additionally, it should be noted here that for the wall targets a relatively free-standing wall is understood. This will probably present no real problem if the evaluation only considers the ability of the munition to create a certain size hole, e.g. a 24-inch diameter breaching hole for troop mobility. If, however, the evaluation must also be concerned with the ability of the munition to provide for personnel incapacitation behind the wall by fragments, either masonry or metal (from the warhead), then complete rooms, i.e. four walls must be constructed. The additional non-target walls are required in order to provide support for the behind-the-wall collection medium (such as 1/2-inch celotex over 3/8-inch plywood witness panels which have been used in previous tests). But, the three non-target walls of the room do not need to be of the same construction as that of the target wall. They (non-target walls) only need to be strong enough to provide adequate support for the collector panels to prevent them from being blown down or apart by overpressures or large fragments (e.g., closely spaced boards such as 2x4's do not by themselves provide adequate support for the witness panels).

This report then, describes two types of targets—masonry walls and bunkers. The targets selected are representative of those that would be expected to be encountered in an urban (MOBA) environment.[1,4] The wall types addressed are triple brick, 4-inch brick over 8-inch block, and 8-inch reinforced concrete. The type of bunker addressed is the earth and timber bunker.

TARGET CONSTRUCTION

Walls

A. Triple brick wall, 10 feet high, made of clay brick.

1. Use grade SW brick. This grade is intended for use where exposed to temperatures below freezing in the presence of moisture.

2. Use facing or common brick. These bricks are of higher quality and greater durability.

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[4] Ellefsen, R., Coffland, B., & Orr, G. Urban building characteristics: Setting and structure of building types in selected world cities. Naval Surface Weapons Center Report NSWC/DL TR-3714, San Jose State University, San Jose, CA, 15 January 1977.

3. Use 2 1/4-inch by 3 3/4-inch by 8-inch brick. This is the standard size for American face brick.

4. Use cement mortar consisting of 1 part Portland cement to 1 part masonry cement to up to 6 parts mortar sand. The Portland cement should conform to ASTM C150, Type I. The masonry cement should comply with ASTM C91, Type II. This mortar is commonly used in load-bearing walls.

5. Make mortar joints 3/8-inch to 1/2-inch thick and tool the joints to be concave.

6. Brick should be laid in a full bed of mortar and shoved laterally into place to secure solid bearing and a bed of even thickness, and to fill the vertical joints.

7. Solid brick is preferred; however, if hollow core brick is used, cores should be filled with mortar.

8. Allow mortar to cure 28 days before testing wall.

9. The unsupported span of the wall should be no more than 20 feet in keeping with most building code requirements. The minimum wall span should be no less than 10 feet. Lateral support at the edge of the walls can be accomplished by turning back the corners and stepping the wall down as shown in Figure 1.

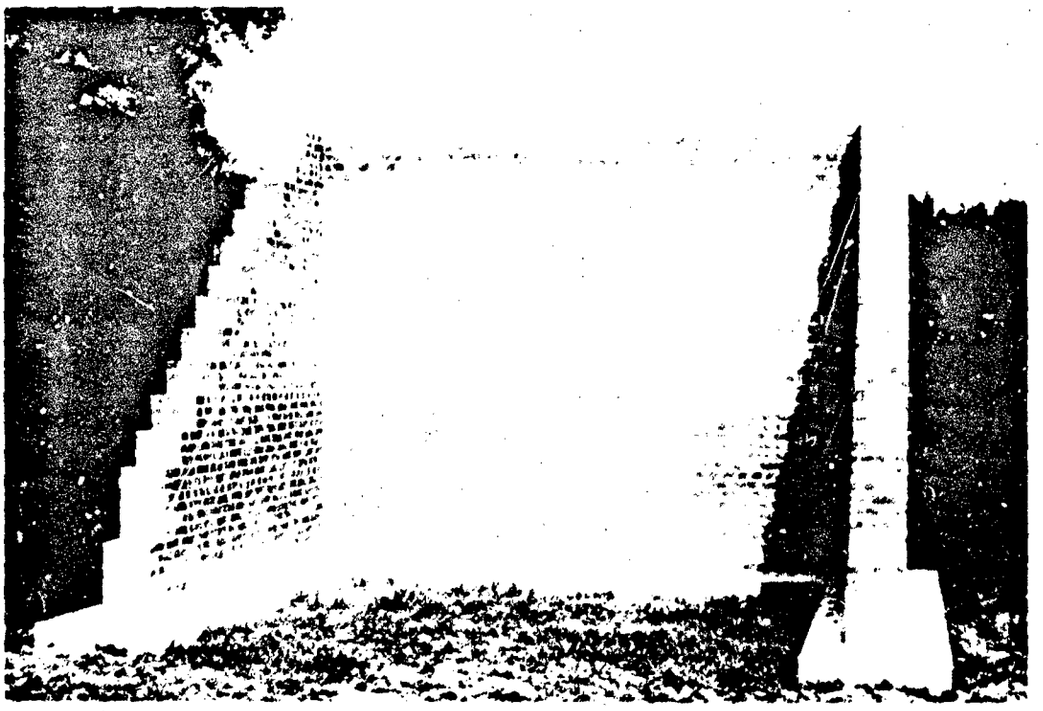


Figure 1. Example of triple brick wall with lateral supports.

10. A 12-inch thick brick wall 10 feet high can support a weight of 1400 lbs/ft^2 along its top in keeping with common building codes. Although the effect of this load on testing is not known, it is felt that simulating such a load would not only be expensive and perhaps impractical but also not necessary for the following reasons:

a. For most penetrating and explosive type weapons, failure of the brick and mortar will be localized and will be due to shear forces or crushing. Although the shear resistance of the wall may be increased by a load, it will be insignificant when compared to the shear forces generated by impact and explosion. Crushing or compressive resistance would not be changed. (Note that this does not address uniform blast load testing which would require preloading the wall.)

b. If the wall is loaded and a hole is breached, the loads will tend to be distributed away from the breach hole. Attesting to this is the fact that the recommended load acting on an arch doorway in a brick wall is not the entire weight of brick above the arch but only that portion of the brick bounded by an equilateral triangle with sides equal to the span of the arch. This is also verified by experience with knocking out holes for doorways in existing brick walls. Usually the only bricks that fall are those inside a triangular portion of the wall above the opening.

For these two reasons, it is felt that the load does not have to be simulated if it is specified that the edge of any hole breached will be at least two hole diameters away from the top and ends of the wall. However, it is also recommended that the load effect be examined in more detail with some simple experiments.

11. Lay and bond bricks by method shown in Figures 2a-d, using a header course every seventh course. These figures also show the method for turning corners.

B. Brick and concrete block wall, 10 feet high.

1. Use brick as specified for triple brick wall (Target Construction, Walls, Section A, items 1 and 2).

2. The concrete blocks should be:

a. Heavyweight units weighing 40 to 50 pounds each for 3 core units and 25 to 30 pounds each for 2 core units.

b. Units having nominal dimensions of 8 inches by 8 inches by 16 inches (actual dimensions 7 5/8 inches by 7 5/8 inches by 15 5/8 inches).

c. Three core units (more strength for spall purposes) are preferred. If they are not available, two core units are acceptable.

d. Units with a face shell thickness between 3/4 and 1 1/4 inches.

e. In compliance with either ASTM C90, 1952, or Federal Specification SS-C-621 for load-bearing units. (These include specifications for compressive strength and moisture content.)

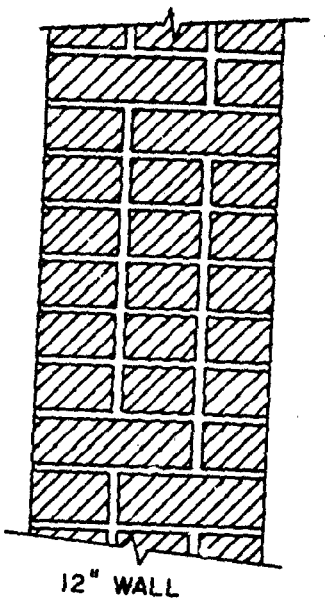
3. Use mortar as specified for triple brick wall, Target Construction, Walls, Section A, item 4.

4. Comply with Target Construction, Walls, Section A, items 5, and 8 - 10.

5. Use full mortar bedding in laying block (used for load-bearing walls).

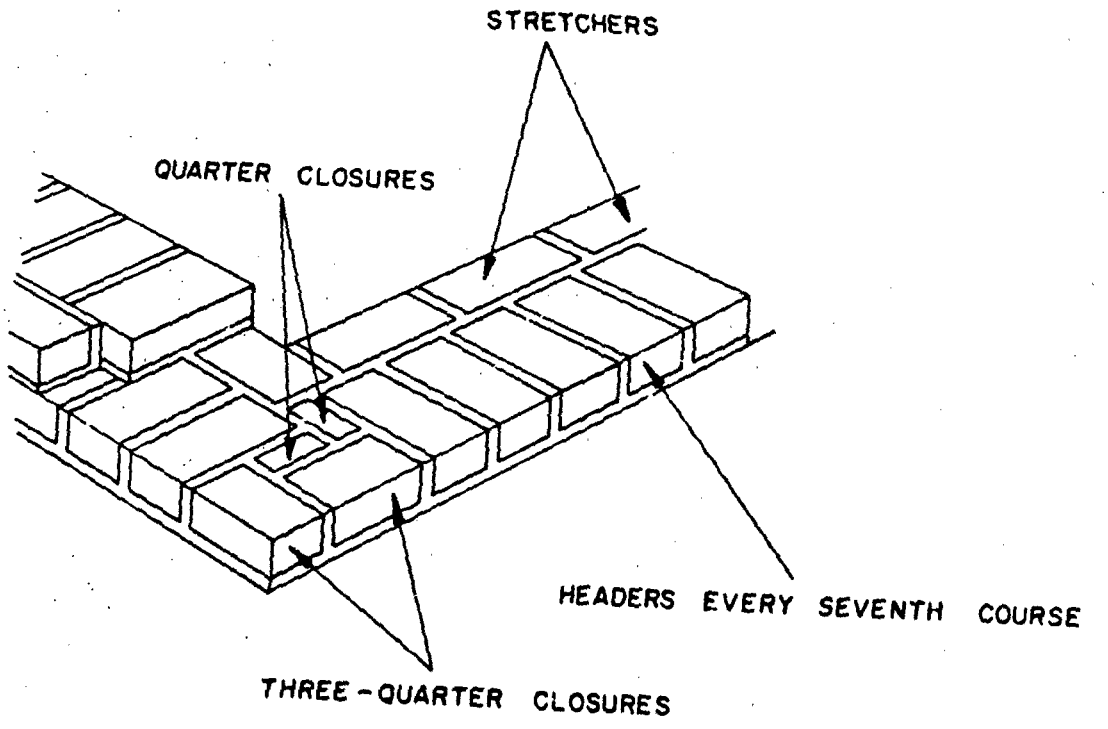
6. Keep blocks dry until wall is constructed by covering with plastic and keeping off ground. Cover top of wall if work is stopped before completion to keep rain out of cores. Use solid or cap blocks over top course of wall to keep out moisture.

7. Bond bricks to concrete block by using a header course every seventh course as shown in Figure 3. (This technique is for load-bearing walls.) Figure 4 shows an example of this type wall.



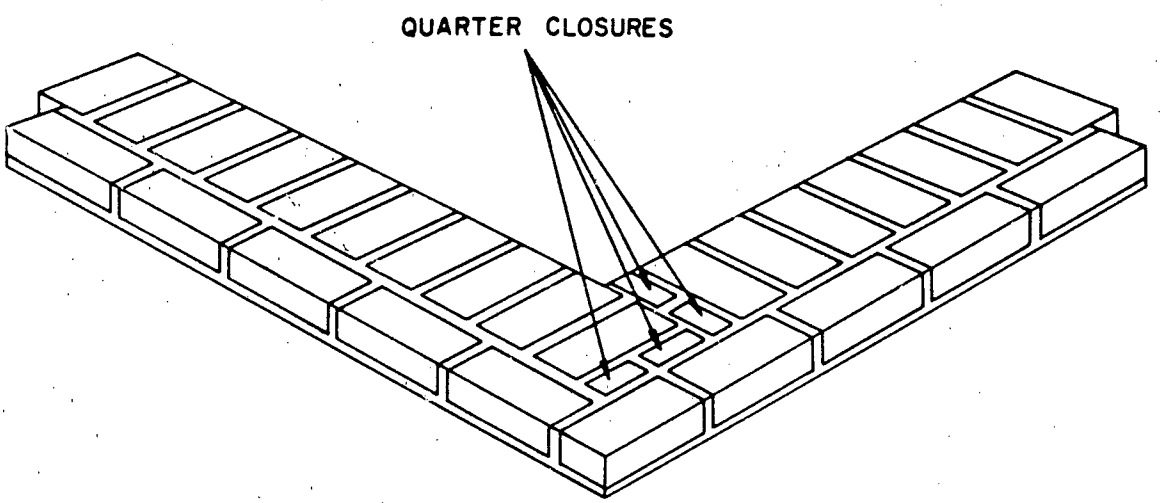
12" WALL

a. CROSSECTION

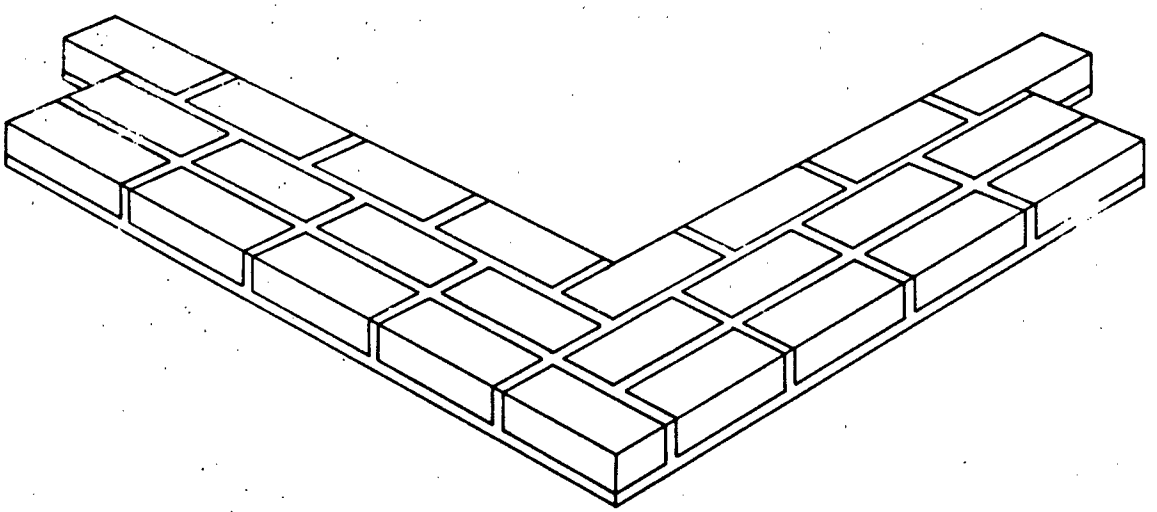


b. FIRST COURSE

Figure 2. Laying and bonding detail for triple brick wall.



c. SECOND COURSE



d. THIRD COURSE

Figure 2. Laying and bonding detail for triple brick wall.

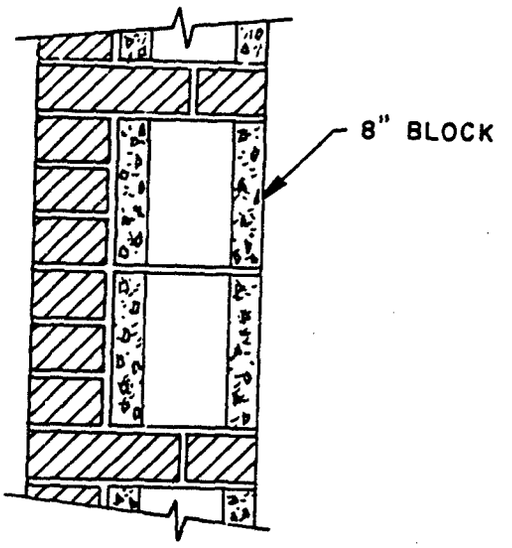


Figure 3. Bonding detail for brick and block wall.

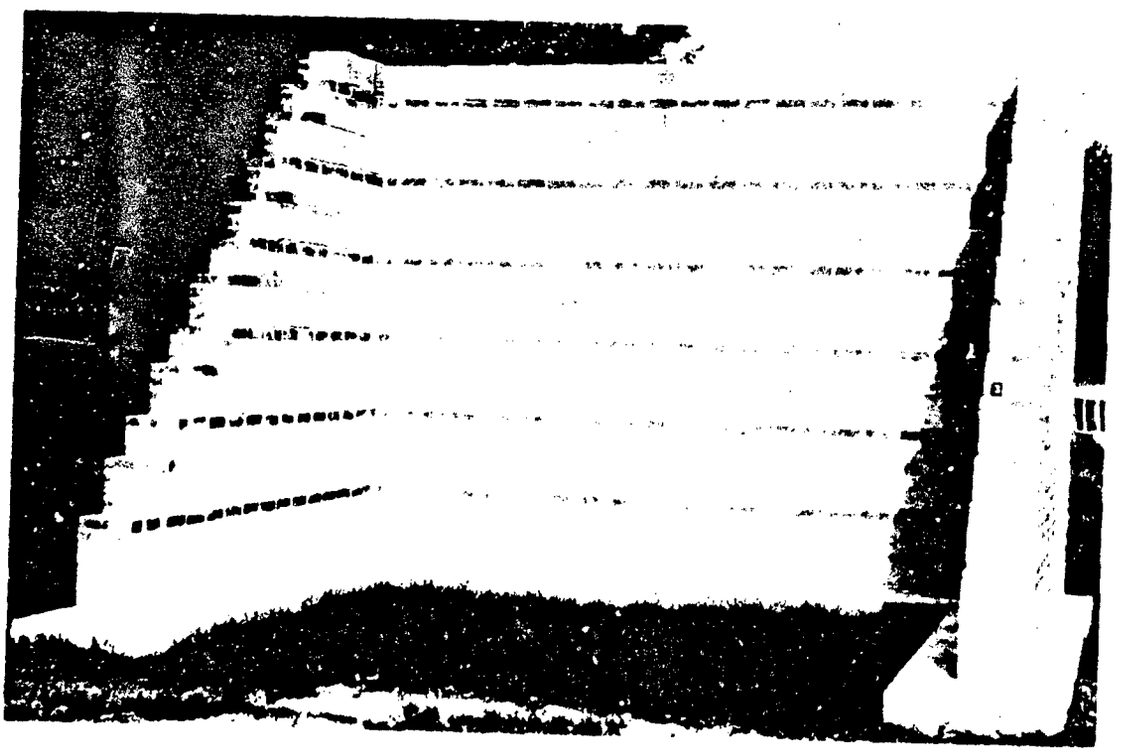


Figure 4. Example of a brick and block wall with lateral supports.

C. Reinforced concrete wall, 8 inches thick.

1. Compressive strength of concrete should be 3500 psi (achieved normally after 28 days curing).

2. Specify moist curing for first 7 days.

3. Specify one slump test for each wall. Slump should be from 3 to 6 inches. Make test in accordance with ASTM C143.

4. Specify five 6-inch-diameter, 12-inch-long cylindrical concrete samples be taken on day of pouring for each wall. Samples should be taken, cured, and tested for compression in accordance with ASTM C172-54 and ASTM C31-49.

5. One sample should be tested at 7 days and compared with appropriate strength versus time curves (e.g. Figure 5) Appropriate changes in test day(s) can then be made so that weapon test(s) will occur near (no less than) the 3500 psi strength. This (the 3500 psi strength) will normally be at 28 days. If the weapons test(s) does not occur at the 3500 psi/28 day time, then the other concrete samples should be tested at the beginning of weapon test(s). If the test(s) are extended over a long time period (several months), then samples should be tested at the beginning of each test segment.

6. The appropriate sections of the American Concrete Institute's Publications ACI 318-77, "Building Code Requirements for Reinforced Concrete," and ACI SP-15, "Specifications for Structural Concrete for Buildings," should be followed for curing and placing concrete. These take into account such things as vibrating the concrete, permissible height of drop for pouring, etc.

7. For explosive tests, wall heights should be 4, 6, 8 and 10 feet for charge weights up to 2, 4, 20, and 50 pounds, respectively. This is based solely on size of front and rear crater dimensions, and the edges of these craters should be at least one crater radius away from the wall edges.

8. For penetrating rounds, Figure 6 gives a graph of permissible wall height versus change in momentum of the projectile to prevent flexural failure of the wall.

9. Wall length should be at least as great as height.

10. Size and spacing of reinforcing bars are indicated in Figure 7. (Note that the wall is double reinforced; i.e., reinforcing at front and rear of wall.)

11. Typical wall construction is shown in Figure 7 for a 10-foot high wall. Other size walls should be constructed in a similar fashion.

Bunker

A. Sand

1. Specify pit run sand and keep it dry by covering it until ready for testing.

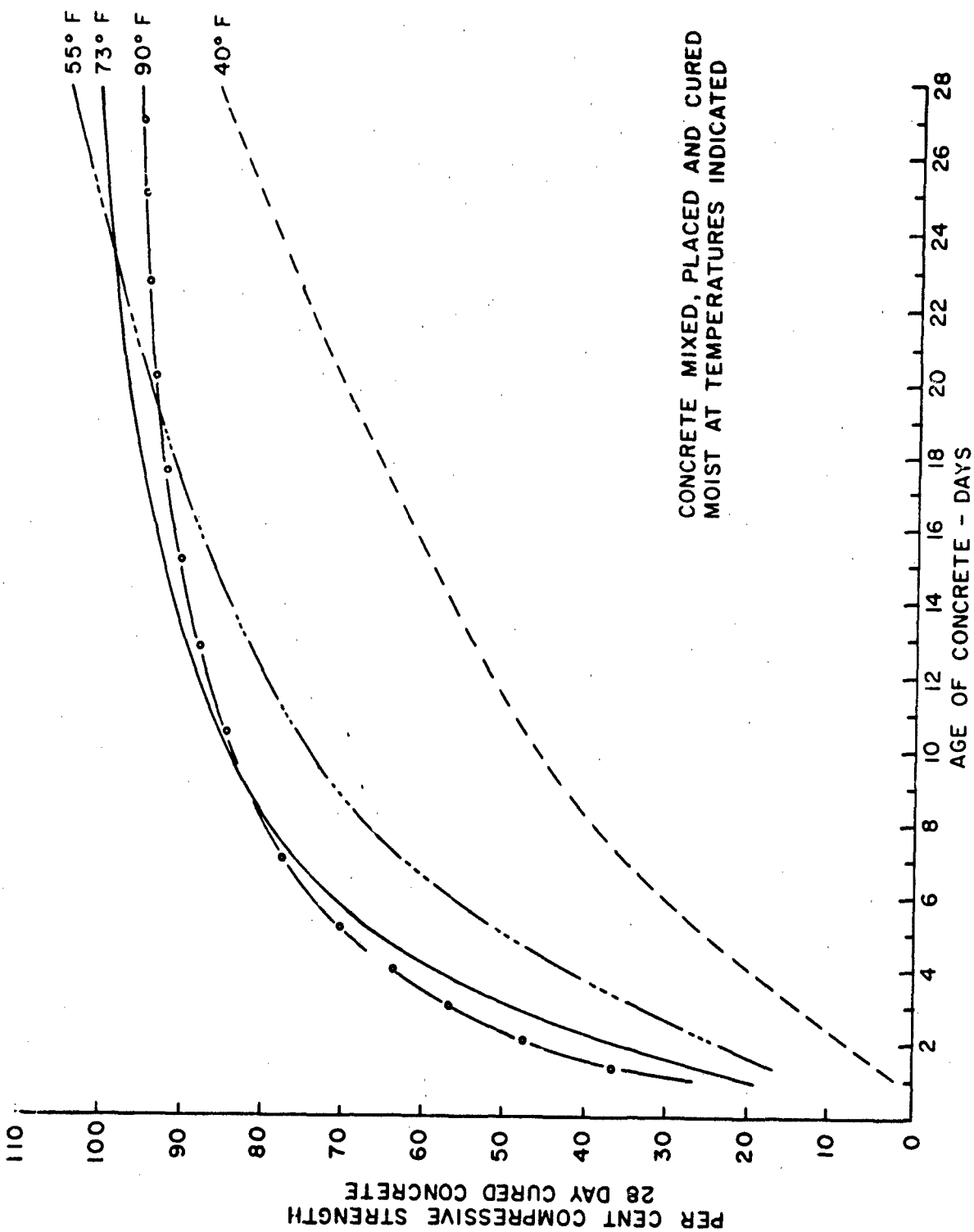
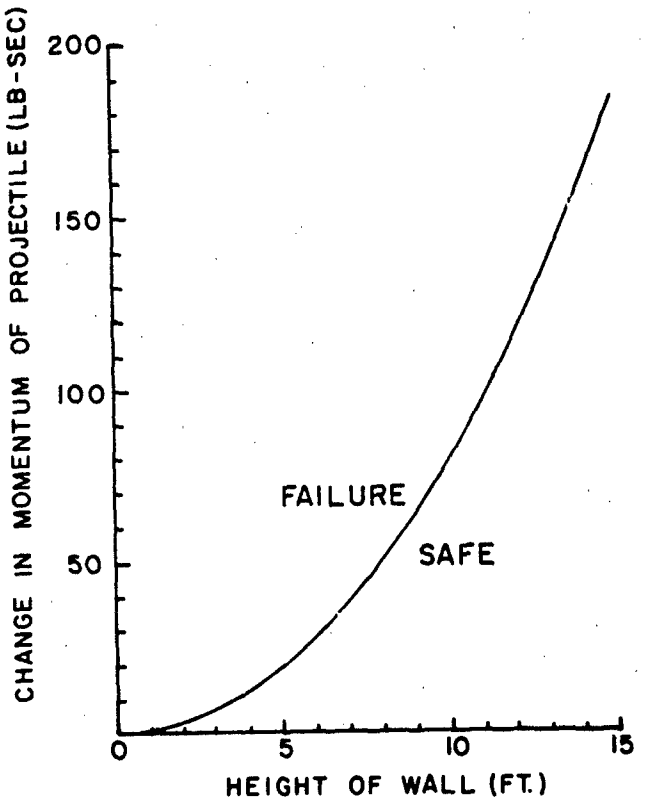


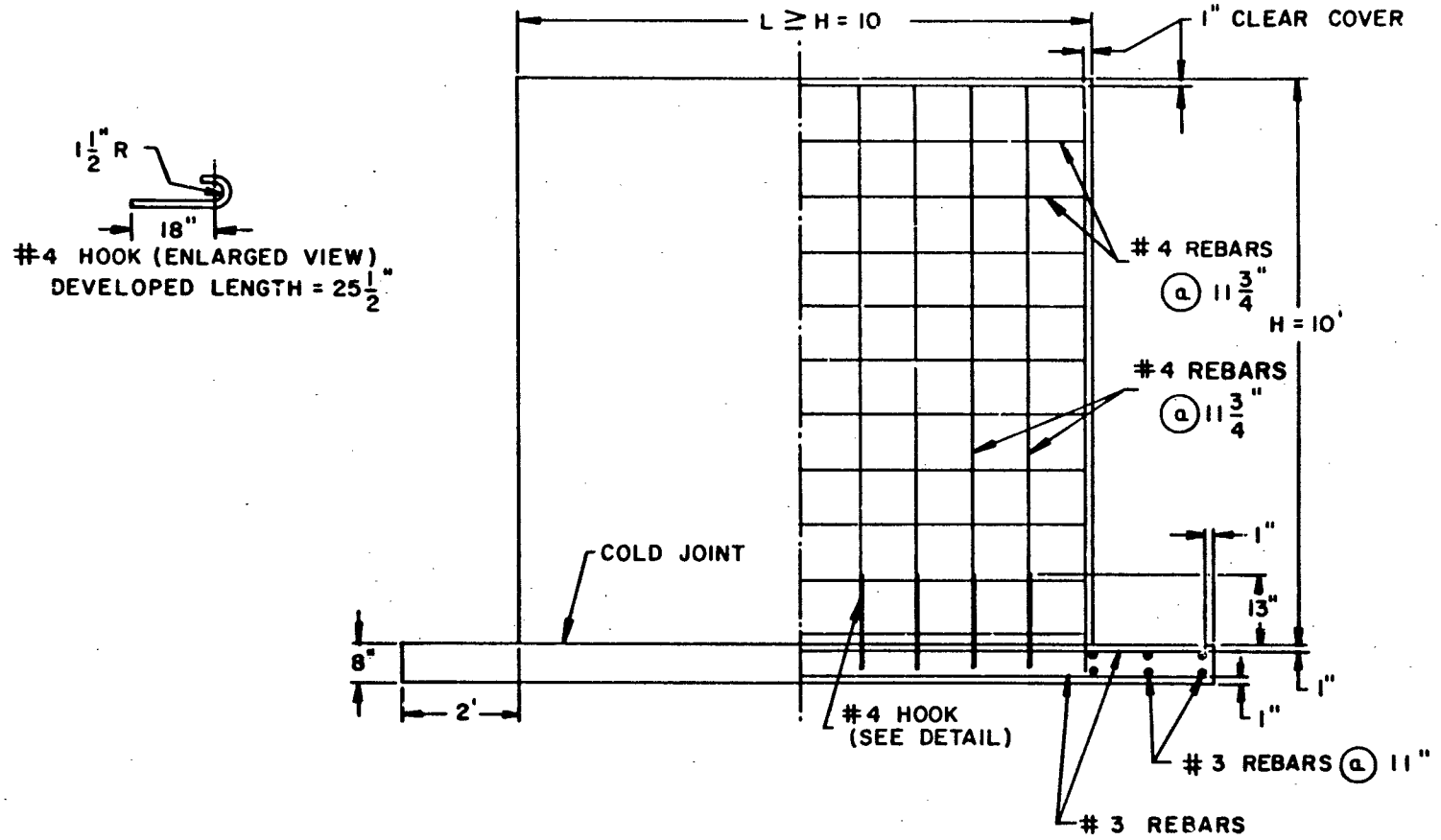
Figure 5. Variation of concrete strength as a function of time.



ASSUMPTIONS:

1. WALL HEIGHT ≅ WALL LENGTH
2. PROJECTILE IMPACT GENERATES IMPULSIVE LOAD
3. WALL IS CONSTRUCTED AS SHOWN IN FIGURE 5

Figure 6. Design chart for wall height.



a FRONT VIEW WITH CROSSECTION

NOTES:

1. DIMENSION TOLERANCE: INCHES = $\pm \frac{1}{4}$", FEET $\pm$ 1"
2. ALL REBARS ARE ASTM A 615-68 GRADE 40
3. FOOTING WITH HOOKS IS POURED FIRST AND THEN WALL SECTION
4. FOR OTHER SIZE WALLS SPACING OF REBARS MAY HAVE TO BE CHANGED SLIGHTLY FOR EQUAL SPACING

Figure 7. Construction details for concrete wall.

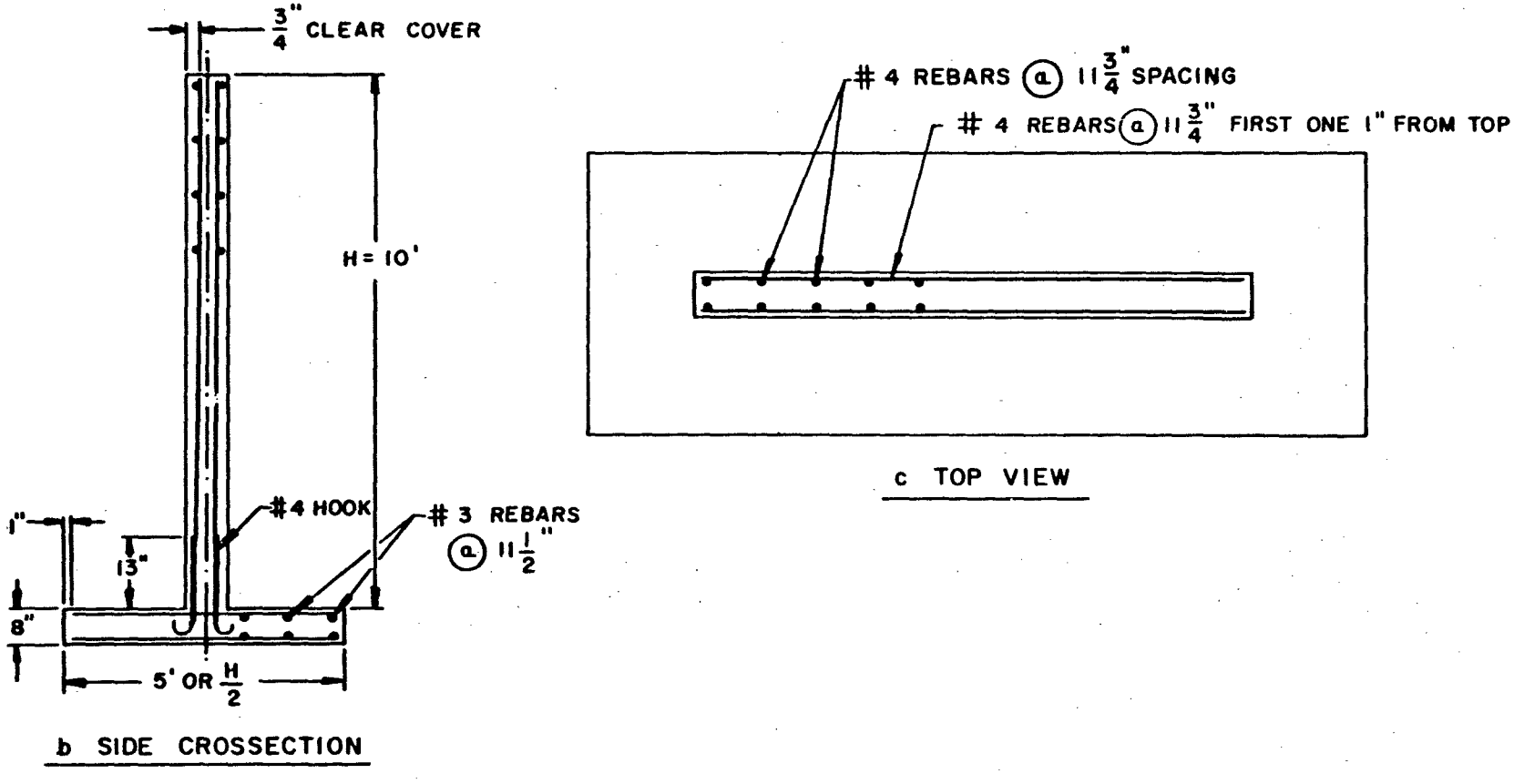


Figure 7. Construction details for concrete wall.

2. On day of test, send two samples to a soil testing laboratory for grain size analysis and moisture content.

B. Timber

1. Type

a. Use rough cut timber to retain exact dimensions.

b. Use No. 2 dense (longleaf) SR Southern Pine (bending stress: 1400 psi).

2. Connections

a. Use 1/2-inch-diameter, 9-inch-long lag bolt for connecting 6-inch to 6-inch x 6-inch posts. This will mean that the lag bolt penetrates 1/2 the thickness of the post.

b. Drill a 1/2-inch-diameter hole through the 6-inch by 6-inch timber and then a 5/16-inch-diameter hole to a depth of 3 inches in the post for a lead hole.

C. Construction details.

Details of construction for earth-timber fortifications can be found in Figure 8.

RECOMMENDATIONS

1. It is recommended that these interim standards be adopted by the US Army for the testing and evaluation of weapons effects (penetration, breaching and personnel incapacitation) in MOBA.

2. It is also recommended that some test walls be constructed and a limited weapons/munitions test be conducted to validate the target construction standards/design and data (weapons/munitions effects).

3. All test reports should include specific target information as listed in the Appendix.

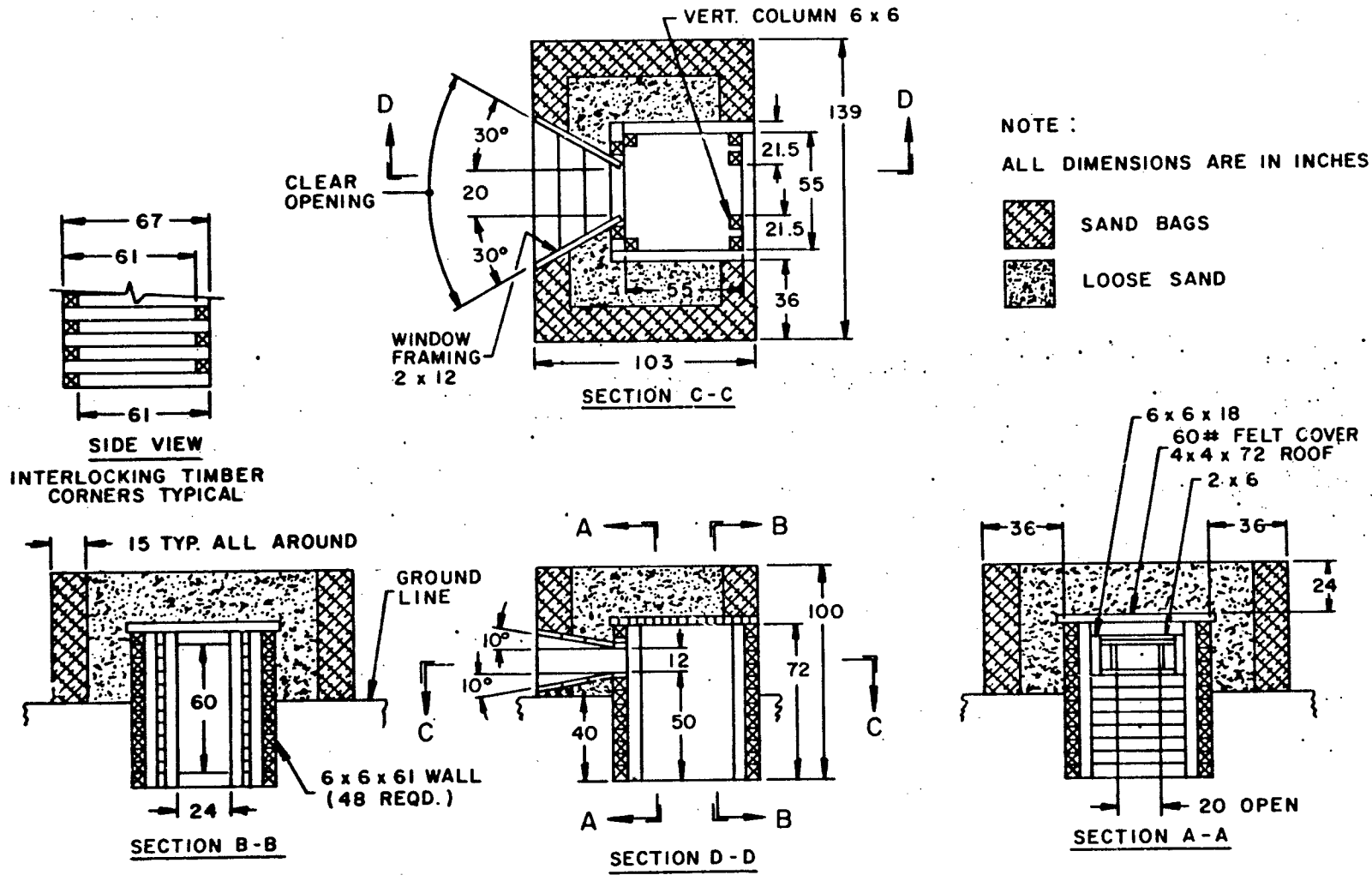


Figure 8. Construction details for earth-timber fortification (bunker).

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APPENDIX

TARGET INFORMATION FOR REPORTS

Target Information for Reports

1. Triple brick walls

   a. Grade of brick used

   b. Mortar mix used

   c. Bonding detail

   d. Curing time; i.e., date walls laid and date of test

2. Brick and concrete block wall

   a. Type of brick used

   b. Type of block used

      (1) Weight of unit

      (2) Number of cores

      (3) Face shell thickness

      (4) Mortar mix

      (5) Bonding detail

3. Reinforced concrete walls

   a. Compressive strength

      (1) Date wall and samples poured

      (2) Date of each sample tested, with corresponding compressive strength information.

      (3) Date of weapons/munitions test and corresponding compressive strength of sample.

   b. Curing conditions; i.e., number of days moist cured

   c. Aggregate use

   d. Type of cement mixture

e. Reinforcing

(1) Size of rebars

(2) Spacing of rebars

4. Bunkers

a. Sand– type used

b. Timber

(1) Type

(2) Grade

(3) Bending stress